SPECIFIED GAS EMITTERS REGULATION

SOIL CARBON CUSTOM COEFFICIENT/PROTOCOLS GUIDANCE DOCUMENT

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Version 1

Alberta
ENVIRONMENT

Prepared by the Department of Agriculture and Food

LBERTANS CLIMATE CHANGE

Disclaimer:

The information provided in this document is intended as guidance only and is subject to revisions as learnings and new information comes forward as part of a commitment to continuous improvement. This document is not a substitute for the law. Please consult the *Specified Gas Emitters Regulation* and the legislation for all purposes of interpreting and applying the law. In the event that there is a difference between this document and the *Specified Gas Emitters Regulation* or legislation, the *Specified Gas Emitters Regulation* or the legislation prevail.

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Introduction

The document has been developed to provide guidance on developing custom soil carbon coefficients under the *Specified Gas Emitters Regulation* (SGER).

In particular, this Guidance material was prepared to assist those project developers who wish to use the flexibility provision of the Tillage System Management protocol (Sept. 2007 v1), or derive their own protocols from developing regional coefficients for carbon sequestration only. The Tillage System Management Protocol Flexibility Section states:

A project operator may define and justify site-specific Soil Organic Carbon (SOC) sequestration and N_2O coefficients, adjusted for baseline conditions. These factors may be substituted for the generic emission factors indicated in this protocol document. The methodology must ensure reasonable accuracy and certainty, and be based on principles-based guidance from Alberta Agriculture and Food. Further, these emission factors must be assessed to ensure that the project developer has properly accounted for any impact on emission factors, assumptions and assurance factor estimates in this protocol.

This document represents the 'principles-based' guidance mentioned in the protocol. Separate material will address customizing N_2O and Energy coefficients.

Assumptions

Due to the non-point nature of GHG emissions in agriculture, the state of knowledge of greenhouse gases is a developing science. In many cases, we lack understanding of the interaction of management practices with the three greenhouse gases (GHGs) involved in agriculture – $C0_2$, N_20 and CH_4. Further, measuring GHG emissions for every production system across the province's soil-climate-cropping-management combinations is simply not possible.

However, process-based models, derived with the best available science, and tested thoroughly under Alberta conditions, can be used to provide reasonable estimates of GHG emissions from different practices in different regions[1]. Prisley and Mortimer (2004) note that when ecological or environmental models are applied in settings with

[1] This is the approach used for the Environment Canada's National Emissions Inventory methodology for agriculture – NCGAVs or National Carbon and Greenhouse Gas Accounting and Verification System for agriculture. The Tillage System Management protocol is also based on this approach.

significant policy, economic, regulatory or social impacts, they should be held to high standards.

The guidance in this document is based on the use of scientifically derived models of carbon accumulation to calculate regional coefficients. In some cases, project developers may develop coefficients based on historical data they either have assembled or have access to in their Project provided that the criteria outlined below are followed and the methodology and data used to develop the coefficients are published in peer-reviewed scientific literature.

Note that the adjusted baselines and assurance factors also apply to any custom approaches, if the flexibility provision in the Tillage System Management protocol is used. Further, an assessment of the custom approach as compared with the current coefficients in the Tillage System Management protocol, based on Agriculture and Agri-Food Canada's National Carbon and Greenhouse Gas Accounting and Verification System (NCGAVS) Century methodology, will be required to use the flexibility provision. See Appendix B for a description of the Century approach.

Guidance:

Step One – Model Evaluation

If a model is used to derive regional coefficients (e.g. at the ecodistrict, ecoregion or Soil Zone scale), an independent third party assessment of the model's accuracy and sensitivity of predicting changes in the Soil Organic Carbon coefficients within the region of interest is required (requirements of third party outlined in Appendix B).

The model or pertinent algorithms used in the model must be described in the peer-reviewed scientific literature and must be well documented, (e.g. the CENTURY model has over 1000 citations in the literature). A model needs a track record of relevant peer-reviewed scientific publications to ensure that the basic algorithms within the model are stable.

Model assumptions must be stated, limitations and uncertainties must be disclosed, and a user's manual must be available. It must also be established that the model works in the Alberta conditions where it will be applied, using a scientific approach such as is documented in Grant et al. (2001), Prisley and Mortimer 2004, and Smith et al. (1997). The model must be validated against relevant long-term site data that meet the following criteria:

i) are measured within the soil zone and order for which the coefficient is calculated;

ii) are of 10 years or longer in duration;

iii) are randomized with adequate replication;

iv) have a reference tillage treatment;

v) have depths of sampling that are reasonable and consistent (e.g. 15 cm or within the A horizon).

A sensitivity analysis must be included to show the degree to which model results are affected by changes in the key input parameters important to the application of the model across the range of parameters for which it will be applied. Key parameters must include:

- values of SOC and nitrogen (N) used for initialization;
- values of SOC and N at the start of the project;
- seeding date;
- climate;
- crop type; and,
- crop yield.

The evaluation results must be published in the scientific literature and the implications of their use for developing regional coefficients in Alberta must be assessed and reported upon by an independent third party,. The model must be approved by the Alberta Government before it is used to develop regional coefficients.

Step Two - Application of the Model/Science to Develop Regional Coefficients

Once the model is validated with measurements made using detailed site data, the model must be consistently, systematically and accurately applied using representative site data at detailed scales, before being aggregated to represent the desired regional scale[2]. This transfer of information is called ***scaling up*** and will need to be published in the scientific literature, and validated by independent third parties (see Appendix A for more guidance and an example scaling methodology used by the NCGAVS group in Agriculture and Agri-Food Canada). This step is as critical as the testing phase of the model described above, and must be defensible and transparent.

Several key considerations need to be taken into account to achieve a defensible, scientifically sound scaling approach for the modeled results. These include the requirement for detailed data on crop rotations, climate, soils and management that adequately represent the region for which the coefficient is calculated. Multiple model runs are required to account for variances in crop rotation sequences, climatic patterns, soils, etc.

Key Considerations:

1. Analytical Units and Databases – Use the most recent sources of data (e.g. Soil Landscapes of Canada (SLC, Soil Landscapes of Canada Working Group, 2007.) or AGRASID soils database, (Brierley et al. 2001)); with clear decision rules or best practice guidance for selecting the modal soil, landscape segment, range of crop rotations, tillage intensity data, climate data; and any other management data. Systematically organized databases must be publicly available and summarized within the publication of the scaling methodology in the scientific literature. The SOC must be reported in mass units, not as concentrations.

[2] Note – Those using historical data to establish rates of change of SOC over time will need to adapt these steps to extrapolate the measured data to regional coefficients. SOC measurements for the baseline and project conditions must be clearly referenced and follow the parameters of selection outlined in Step 1 above.

2. Model Initialization – A consistent, systematic approach to initializing the model at representative sites within the region must be used. Calibration with historical measurements (e.g. from 10 to 20 years ago) is required to identify equilibrated model starting points before applying the model to calculate changes in SOC. The soil layer file data of SOC levels in cultivated conditions in the AGRASID soils database may be used. Assumptions about historical management practices must be described in detail and be supported by the expert opinion of qualified professional agrologists who are familiar with farming practices in the area. Data sources must be clearly referenced and documented and follow the parameters of selection outlined in Step 1 above.

3. Model Runs – Once model initialization is complete, starting levels for model runs at representative existing sites must be used to run the model. Soil carbon levels at these sites must be documented using measured values from composite samples within the upper, mid and lower slope positions with a field, with the location of each point of the composite sample referenced with a GPS unit. The results of the composite sample analysis must be weighted to proportionally represent a field, according to the amount of each landscape class (e.g. upper, mid, lower) identified for the dominant soil component in the AGRASID soils database.

4. Input Database Suitability – The assessment of the suitability of crop-soil-management-climate databases for input to the models, and the databases overlay into the analytical unit must be clearly presented for the baseline and for the project.

5. Customized Coefficients – The methodology for calculating coefficients must be weighted averages of multiple runs considering items from Number 1 above (e.g. not a single representative site), as illustrated in Appendix A. The coefficients must represent the difference between the amount of SOC sequestered with and without the practice change (baseline condition). Comparisons of measured and modelled SOC coefficients can be found in scientific journals such as the Canadian Journal of Soil Science.

6. Uncertainty Assessments of the Coefficients – A probabilistic assessment of the certainty of the predicted model output/regional coefficients must accompany the assessment (e.g. a Monte Carlo or similar analysis).

7. Data Augmentation - Expert opinion may be used to augment the data requirements of the model (e.g. historical management information, typical crop rotations, typical seeding date) provided that opinions from qualified professional agrologists who are familiar with farming practices in the area are documented and submitted.

8. N_20 and energy coefficients in the Tillage System Management Protocol may be used with custom SOC coefficients.

9. Adjusted baselines and assurance factors apply to any custom approaches, particularly when using the flexibility provision of the Tillage System Management protocol.

10. Given that the science of modelling soil carbon sequestration is currently under development and that measured data on rates of carbon sequestration in Alberta-like conditions are limited, the following requirements are in place to ensure that high standards are applied to the calculation of custom coefficients.

    i) Scale – The operational aggregation level for a regional coefficient is the soil zone scale (e.g. Black, Dark Brown);

    ii) Based on western Canadian research results, it is expected that custom carbon coefficients for a practice change from full tillage to no tillage will not exceed 0.84 tonnes CO_2e ha^{-1} y^{-1} or 0.33 34 tonnes CO_2e ac^{-1} y^{-1} in the Parkland protocol area and 0.48 tonnes CO_2e ha^{-1} y^{-1} or 0.22 19 tonnes CO_2e ac^{-1} y^{-1} in the Dry Prairie protocol area. These values are soon to be published in the scientific literature, and are based on measured changes across the prairies. These .may increase as new information becomes available in the future. The onus is on the project operator to prove that custom coefficients should be higher, based on evidence from peer-reviewed scientific publications of long-term measurements

of carbon sequestration rates in conditions that are similar to the area for which the custom coefficient is proposed (e.g. including variations in soil, management, climate, etc.), as well as the model application results described above.

The process used to develop the regional coefficients must be evaluated and reported upon by independent third parties, including recommendations regarding the use of the developed regional coefficients. The coefficients must be approved by the Alberta Government before they are used.

References

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Appendices

Appendix A: Century Application at Regional Scales

Carbon Change Estimation Method Used for Agricultural Practice Changes

Adapted from McConkey et al. 2006. The following discussion illustrates how the Century 4.0 model (Parton et al. 1997, 1998) was used within NCGAVS to derive carbon change coefficients for the National Inventory Report. The method was used to calculate coefficients associated with tillage change for the Parkland and Dry Prairie Reporting Zones. It's expected a similar approach will be used to deriving regional coefficients.

Agricultural Activity Data:

The changes in soil organic carbon (SOC) with and without a practice change were superimposed on simplified mix of crop rotations and management practices that existed in each SLC polygon from 1990 to 2000 (derived from Census of Agriculture data), as outlined in Fig. 1.

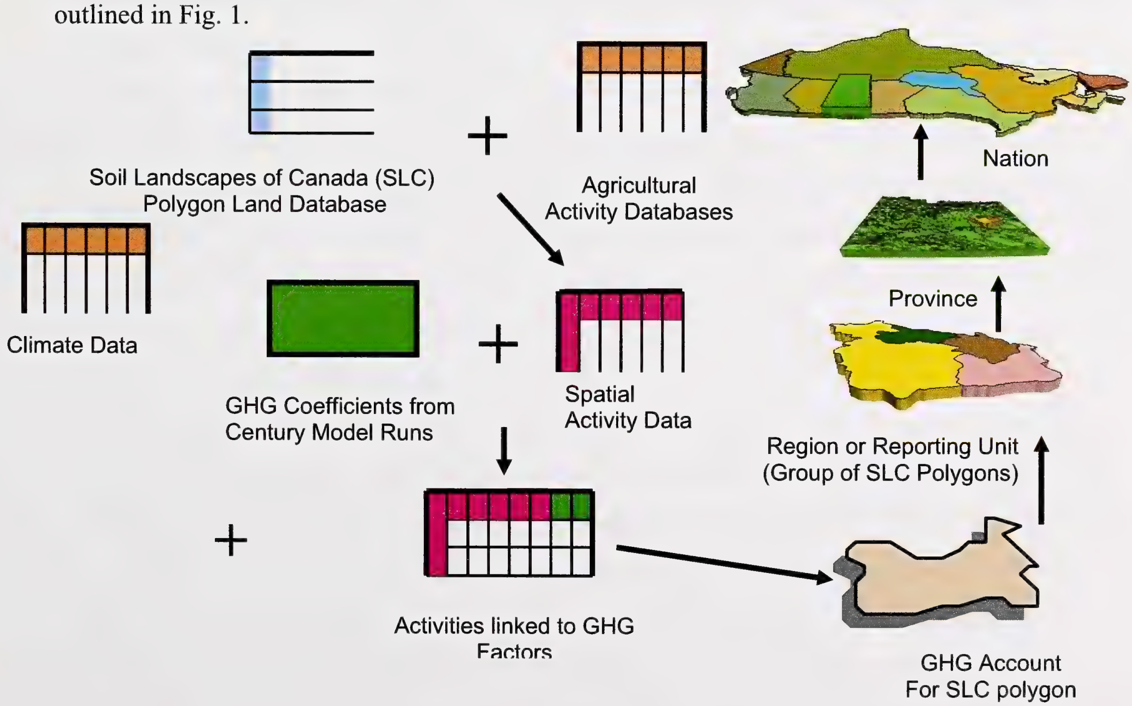


Figure. 1. *The general approach of the Century model / NCGAVS application.*

Climate Databases:

The effect of variability in weather patterns was represented by inputting the patterns that existed form 1961-2000 period.

Crop Rotations:

The representation of a mix of crops and management practices for model input is difficult. One solution is to represent the mix of crops and management distributed in space at one time as a mix of crops and managements distributed in time at one place to define the "base temporal crop mix" needed for model input.

The mix was simplified by excluding those crops and practices that represented 5% or less of the agricultural land area in the SLC polygon. Except in a few cases where the SLC crop and practice mix was essentially uniform, the SOC difference between with and without a practice represents the effects of incremental changes in practice rather than complete change to a new practice. For example, since many crop mixes contain some perennial crops, the difference between with and without perennial crops almost invariably refers to the effect of adding additional perennial crops to land that already has some perennial crops. Similarly, the SOC change for switching from full tillage to no-till would refer to a situation of adding no-till to land that already had some no-till and reduced tillage practices within the SLC.

Model Runs:

The simulations were run on every soil component described within the SLC polygon database upon which agriculture was assumed to occur (see Fig. 2). Some land-based emission/removals calculations were calculated at a landform scale that was more detailed than the SLC polygon scale.

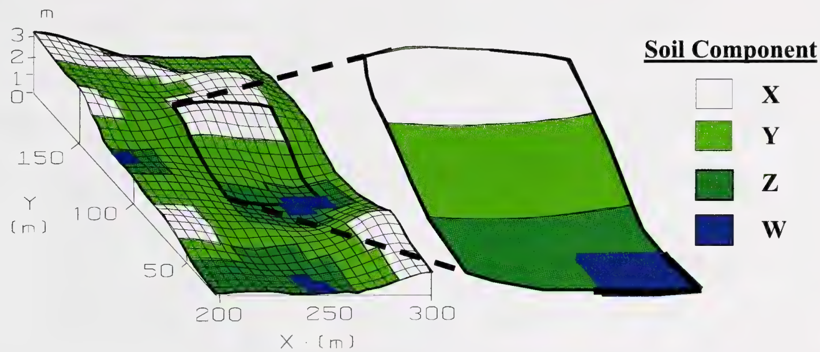


Figure. 2. *A representation of the method of using soil components in the Century model simulations.*

The SOC content in the SLC polygon soil database was used to base the amount of initial SOC of each soil component. The ΔC_{max} and k for equation (1) were fit individually to simulated differences with and without practice change for each soil component in every SLC polygon for which agriculture occurs. An effective linear SOC change factor, F(t) was derived to give the same total change as equation (1) when multiplied by time since the adoption of the new management (adapted from McConkey, 2006).

$$\Delta SOC(t) = \Delta SOC_{max} * (1- \exp(-k * t)) \qquad (1)$$

where:

$\Delta SOC(t)$ is the change in SOC with time (t), since the management change

ΔSOC_{max} is the maximum total SOC change, and

k is the rate constant

$$F(t) = \Delta SOC_{max} * (1-e^{-k*t})/t \qquad (2)$$

Variation in Modelled Results:

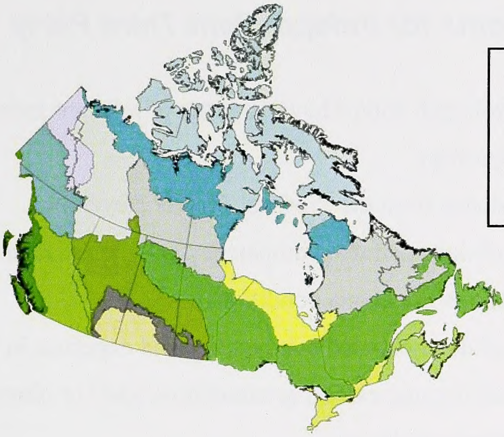
Given the nature of the Century simulations, the results reflect a considerable range of combinations of SOC content and cropland management. Invariably, there was a wide range in simulated SOC differences with and without a practice between soil components

in the same SLC polygon and between nearby SLC polygons reflecting the impact of SOC interactions for these management-soil combinations. Each result refers to an exact management history and SOC state. If it could be shown that a particular area of land shared the exact simulated situation for the past 100 years and the same general history for the last few thousand years, the particular Century simulation should be a good representation for that land area. However since that condition can not be met in practice, the results were averaged across larger reporting zones, assuming that the average represents the best value for use for greenhouse gas reporting on a regional basis. These would not necessarily be representative of the expected C change for a specific area of land.

Averaging over larger zones was done by weighting of each result by the area of agricultural land represented by each soil component-SLC polygon combination.

AnayIticalAnalytical Units vs Reporting Units:

There are advantages to calculating GHG emissions/removals on analysis units of Soil Landscapes of Canada polygons that are at more detailed scales than the reporting units. The increased detail is important for those activities from which GHG emissions/removals are highly influenced by land attributes (e.g. soils, landform, climate). This is increases the accuracy in representing average conditions through aggregation, as described above. The reporting units used by NCGAVS are illustrated in Fig. 3. The coefficients calculated for Dry Prairie and Parkland Reporting Areas are the basis for the Tillage System Management protocol developed in Alberta.



- Reporting Zones combine ecological (ecoregion) and provincial/territorial boundaries
- 22 Reporting Zones have significant agriculture

***Figure. 3**. Zones for carbon change coefficients. The boundary between Dry Prairie and Parkland is the Black-Dark Brown soil zone boundary.*

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Appendix B: Requirements for Independent Third Party Assessors

1) Must be a Professional Agrologist, and/or have 10 years of relevant technical experience in the field of agrology.
2) Must demonstrate independence from the Protocol/Project Developer.
3) Must have at least 5 years of demonstrated competency and expertise in working with soils and cropping systems in Alberta conditions.
4) Must have at least 2 years of demonstrated competency and expertise in working with scientific models of soil organic carbon accumulation and / or nitrous oxide emissions from soils in Alberta conditions.
5) An assessment team may be formed to meet requirements.
6) It is recommended that consensus with at least three other third party assessors be reached concerning the evaluation of scientific models in Alberta conditions and scaling up from detailed sites to regional scales. This needs to be submitted with the protocol for approval.